

The Stochastic Energy Deployment Systems (SEDS) Model

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Outline

- Motivation(s)
- Old Questions and Answers vs. New Questions and Answers
- Model Description
- Sample Results
- Peer review, QA/QC
- Next Steps

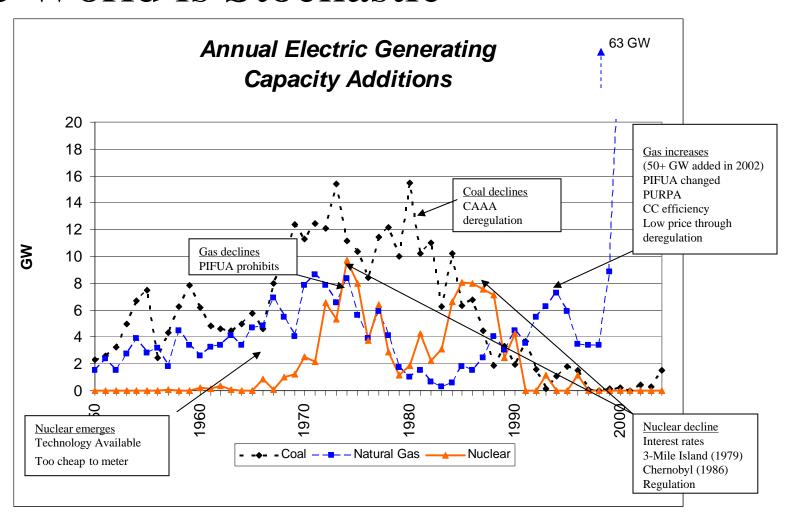
Who Needs ANOTHER Energy Model?

- The SEDS "project" is a model and a strategy, aimed at rectifying multiple ills
 - Models are the tools we love to hate...but have to use
 - Black boxes and distrust
 - Market imperfections of the "modeling market"
 - Hard wired and hidden assumptions (>> more distrust)
 - Slow-to-glacial run time
 - Modelers' are not always subject experts
 - False precision of inputs parameter uncertainty
 - False precision of relationships, dynamics or drivers framing or model uncertainty
 - False precision of outputs(>>more distrust)

Models Are Most Useful IF:

- They are widely vetted
 - Requires development/use by a wide community
- They are widely used
 - By decision-making staff
 - Requires user-friendliness, quick run time, easy input, transparency, well-documented, easy access, inexpensive software
- They are flexible able to accommodate:
 - Market diversity
 - Changes
 - Constraints
- They are built with specific uses in mind
 - Markets, technologies, policies, metrics
 - Major drivers emphasized

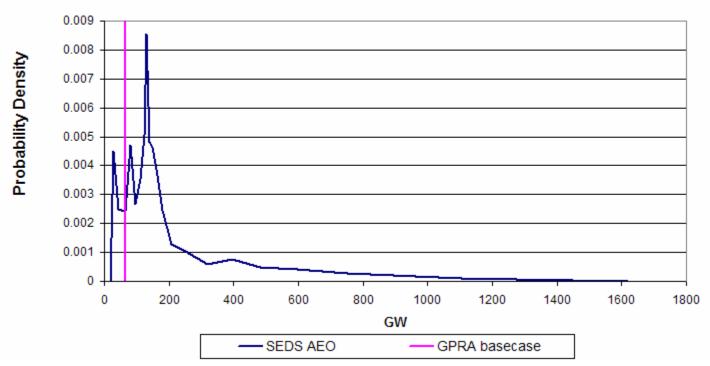
The World is Stochastic



What Might a Stochastic Model Show You?

• Incorporating uncertainty into an energy market model conveys significantly more information than a single point estimate

Likelihood of RE capacity in 2050



Project Objectives

- "..develop an energy modeling capability that explicitly takes into account the uncertainties that we all know exist.."
- Focus on the major market drivers keeping SEDS "relatively simple."
- "..facilitate the on-site direct use of SEDS" by DOE staff and others.
- Bring a wide range of modelers into the development process to ensure quality and wide-spread use.

Old Q&A vs. New Q&A

A Paradigm Shift....

We Used To Say:

• "Our technology will have exactly these characteristics in year X"

• "Oil and natural gas prices will take exactly this path over the next 50 years"

• "Our programs will avoid oil imports by exactly X mmbpd in 2030"

Now We Can Say:

- "There is variability in the technology market and uncertainty in technology development; we're 95% confident that our technology will have characteristics within a certain range around by year X," OR "We're 95% confident that between year X and Z, our technology will have a certain range of characteristics..."
- "There's natural volatility in these markets; we're 95% confident that the markets will move within certain ranges over time, and that each year may have some up or down movement within a certain range..."
- "Given the uncertainties in the market and in R&D, we're 95% confident that we will avoid between X and Z mmpbd of oil in 2030..."

Old Q&A vs. New Q&A

A Paradigm Shift....

We Used To Say:

 "Our R&D will be 100% successful across the department and the benefits will be X"

"I'd like to know what would happen if...but I'd need to wait a week for the answer"

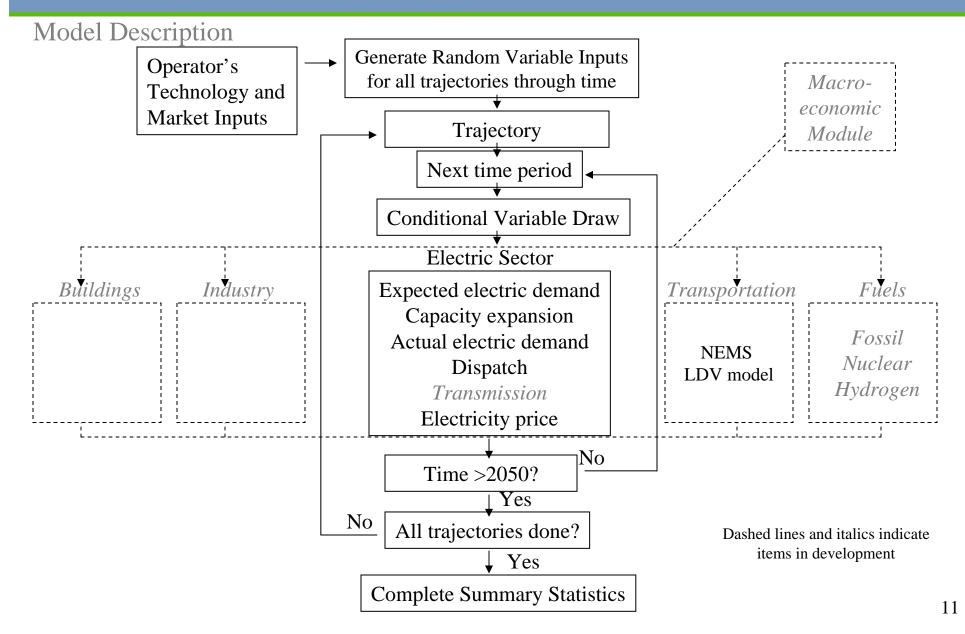
"I don't know whether or not to believe this result because the model is impenetrable"

Now We Can Say:

- "Our technologies have different inherent risks, and different inherent rewards...the portfolio mix of technologies with the most certain rewards is X; the portfolio mix of technologies with the largest rewards is Y; the mix with the best risk-reward ratio given decision maker degree of risk aversion is Z..."
- "I'd like to know what would happen if...so I'll change that assumption on my desktop, and produce an answer immediately...."
- "The model has been developed by multiple subject experts in an open source environment. I'll check what assumptions are being used by looking at the model, and change them if I think they're wrong or like to test an alternative..."

SEDS General Description

- Model of U.S. energy markets: currently only electric sector capacity expansion and alpha version of light duty vehicle transport
 - All major electric prime mover types coal, gas, nuclear, hydro
- Simulation to 2050 (and potentially beyond)
- Explicit treatment of uncertainty with Latin Hypercube simulation
- Simulation not optimization, lack of foresight
- Single national region
- Engineering/economic costs and efficiencies
- Endogenous technology change through learning curves
- Base, intermediate, and peak power markets
- Logit market share for new capacity/retrofits
- Renewable energy supply curves
- Least cost dispatch
- Planned and economic plant retirements



Uncertain Major Market Drivers in SEDS

- Policy/environment
 - Climate change
 - Production Tax Credit
 - Nuclear builds = f (climate change, Yucca Mtn, etc.)
- Fossil fuel prices
 - Natural Gas, Oil and Coal
- Technological advances (e.g \$/kW, capacity factor)
 - Due to R&D
 - Due to learning
- The Economy
 - Electric demand
 - Growth
 - Elasticity

Model Description: Paradigm

Simulation – Not Optimization

- No knife-edge responses
- Logit market share algorithm
- Capable of capturing non-optimal behaviors
- Relatively quick run times

Model Description: Paradigm

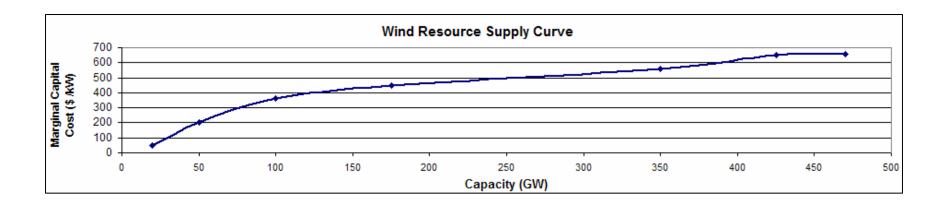
Lack of Foresight

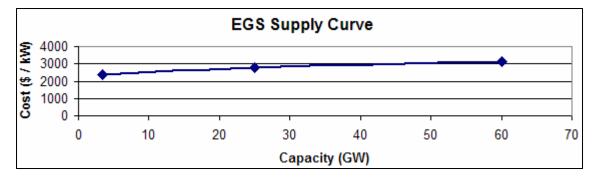
- Especially important in a stochastic model
 - Don't want modeled investors to know the outcome of future uncertainties
- Doesn't know:
 - Future fuel prices
 - Future technology improvements
 - Future policies
 - Future loads
 - Build to model's expectations dispatch to model's reality

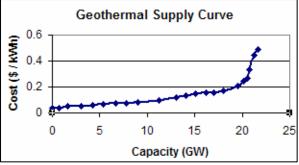
Regions in SEDS

- For transparency and quick run times, SEDS electric market has a single national region, but:
 - We're investigating the tradeoffs associated with having more electric regions
 - Single electric region may be feasible because:
 - Logit market share captures diversity
 - Supply curves capture renewable energy heterogeneity
 - May be able to incorporate some reduced form version of optimal power flow modeling using response surface or neural network
 - Other sectors could have more regions, even if electric sector retains only one region

Renewable Resource Curves







Analytica software environment

- Designed explicitly for uncertainty analysis
 - Operable in deterministic or stochastic mode
 - Easy to input different probability distributions
 - Correlated inputs
 - Conditional probabilities
 - Bivariate distributions
 - Many forms of uncertainty related outputs
 - Confidence intervals
 - Statistics mean, mode, median, std deviation, min, max
 - Spearman correlation
- Built for self documentation
 - Graphical portrayal of functional relationships
 - Function boxes show equations, inputs, outputs, descriptions, relationships
- No-cost, run-only version easily downloadable from net

Model Description: Parameter Uncertainty

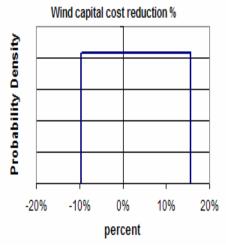
Technology Cost & Performance

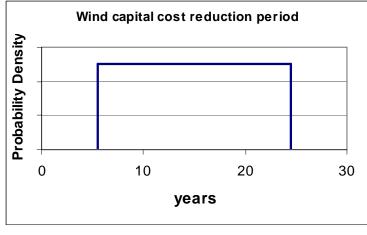
 Uncertainty in Capital Cost and Efficiency

 Each uncertainty modeled through two random variables

Ultimate improvement

- Time to ultimate improvement
 - linear improvement over time

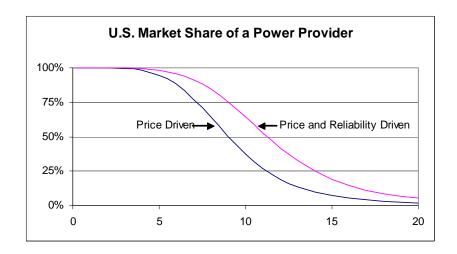




Model Description: Parameter and Market Uncertainty

Market Diversity – Logit Market Share

- Multinomial logit can use more than just price to estimate market share
 - e.g. reliability, ramp-rate



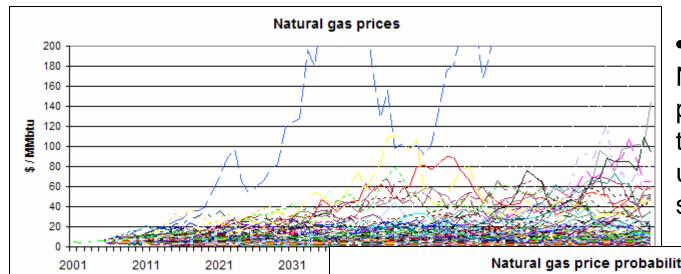
Model Description: Parameter and Market Uncertainty

Modeling Fuel Price Uncertainty

- Eventually, modeled fuel prices will reflect resource depletion, new sources, refining, distribution and uncertainties
- Currently, uncertainty in fuel prices expressed through uncertainty in an annual price growth multiplier g_t $[P_t = (1+g_t)P_{t-1}]$
- Oil price determined by three random variables
- Gas and coal prices determined by uncertainty in their annual price growth multipliers and correlation with oil price

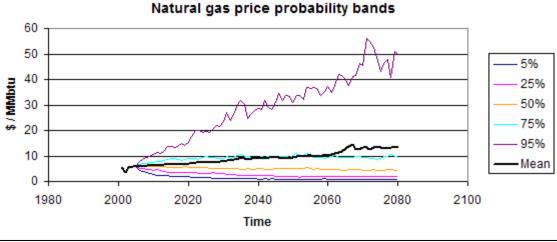
Model Description: Input Parameter Uncertainty

Sample Stochastic Input – Natural Gas



 The evolution of Natural gas price pathways" over time are simulated using Monte Carlo simulations

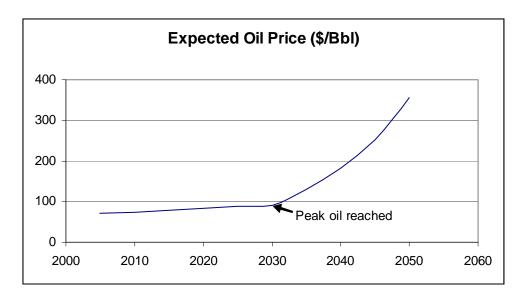
 Inputs and outputs are easily shown using using bands (or confidence intervals)



Model Description: Parameter and Market Uncertainty

Oil Price Uncertainty (illustrative results)

- Annual price growth before "Peak Oil"
- Time to "Peak Oil"
- Annual price growth after "Peak Oil"
- Later version will have representation of world oil market based on D.
 Greene



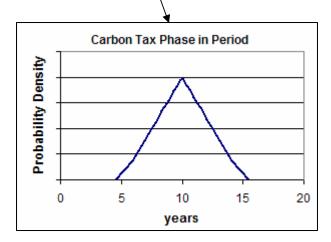
Model Description: Policy Uncertainty

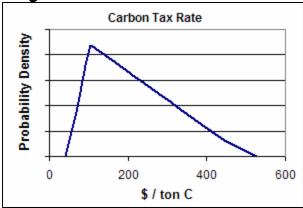
Modeling Carbon Uncertainty (illustrative results)

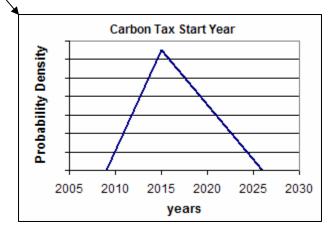
• Size of carbon tax —

• Start date for implementation

Ramp-up time



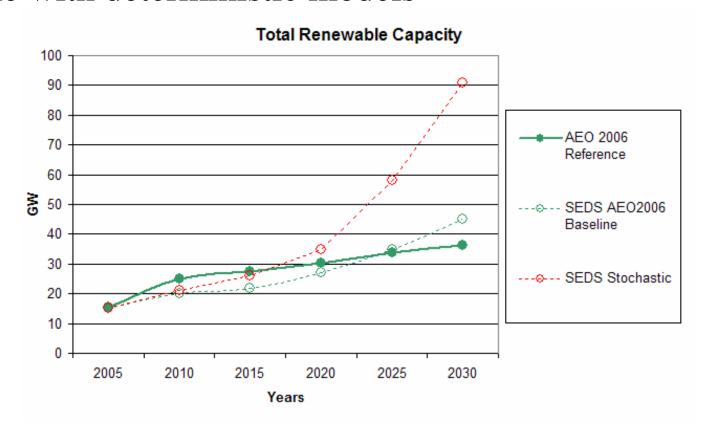




Sample Results

Renewable Capacity

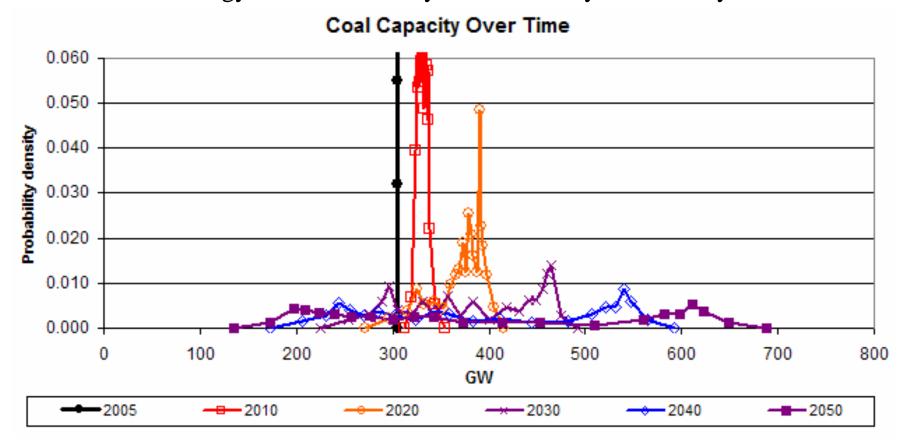
• A stochastic model's projection can yield insights not visible with deterministic models



Sample Results

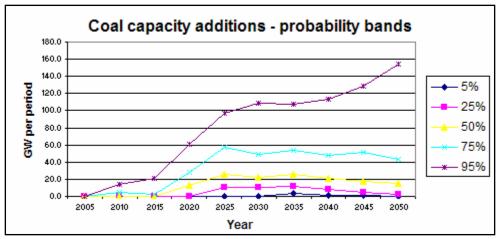
Coal Capacity

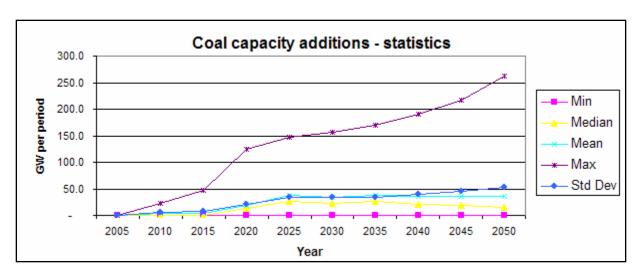
- Uncertainty Increases with Time
- A Bimodal Energy World Driven by Carbon Policy Uncertainty



Sample Results

Information Presentation Variety





Peer Review, QA/QC

- Thus far:
 - Multiple presentations to DOE audiences, including IWG
 - Multiple presentations to lab audiences
 - Presentation to California Energy Collaborative (UCB, LBL, LNL, Stanford)
 - Presentation at REMAP
 - Paper delivered and presentation at conference of US Association for Energy Economics in September
 - Paper delivered/ presentation at workshop sponsored ACEEE/ U of California in November
- Next steps:
 - Ongoing QA/QC by virtue of open-source environment
 - Potential journal submission
 - Formal Advisory Board

Next Steps and Collaboration

- Investigation of important uncertainties (NETL)
- Macroeconomic Module (LBNL)
- Liquid and Gas Fuels (ANL/ NETL)
- Residential and Commercial Sectors (LBNL/PNNL)
- Industrial Sector (PNNL)
- Transportation Sector (ORNL/NREL/ANL)
- "Lite" vs. "Full" versions (NREL, all)
- Regionalization or representation of regionalization's effects (NREL, all)
- Hydrogen (NREL)
- Biomass (NREL)
- Transmission (LBNL, NREL)
- Nuclear Fuel Cycle (?)
- Option value (?)